Faculty of Manufacturing Engineering

DEVELOPMENT OF KENAF WOVEN FABRIC REINFORCED EPOXY AND POLYPROPYLENE COMPOSITE WITH DIFFERENT STITCHING PATTERN

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DECLARATION

I declare that this thesis entitled “Development of Kenaf Woven Fabric Reinforced Epoxy and Polypropylene Composite with Different Stitching Pattern” is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Doctor of Philosophy.

Signature : ………………………………………………………………..

Supervisor Name : Associate Professor, Ir. Ts. Dr. Mohd Yuhazri bin Yaakob

Date : ………………………………………………………………..

DEDICATION

Every challenging work needs self-effort as well as guidance from the elders,

especially those who were very close to our hearts.

My humble effort I dedicate to,

My mother, Munah Bakar and late father, Husin Awang,

whose affection, love, encouragement and prayer,

day and night, make me capable of such success and honour.

My amazing and beautiful wife, Syuhazlein Mamad,

whose sacrificial care for me and our child, Uwais Al Qarni,

made it possible for me to complete this work.

My loving family,

whose always support me in completing this thesis.

ABSTRACT

Natural fibres, due to their eco-friendly nature and sustainability, receive attention from researchers and academics to be used in polymer composites. In this study, the effect of stitching pattern on properties of woven kenaf fabric reinforced polymer (thermoset and thermoplastic) composites was analysed. The hand lay-up followed by a vacuum baggage technique was used to fabricate thermoset composite and a hot pressing technique was used to produce thermoplastic composites. The materials used were epoxy resin and polypropylene, which acted as matrices and woven kenaf fibre as a reinforcement. The composites were made in different patterns of stitches which were divided into two categories, basic patterns which were stitched together by a single cross, including Vertical (V), Horizontal (H), Tilt 30° (T30) and Tilt 60° (T60). The other was a complex pattern, stitch with a double cross, including Box, Tilt 45°/90° (T45/90), Tilt 30°/30° (T30/30) and Tilt 60°/60° (T60/60). Tensile test, impact test and hemisphere test of the composites were evaluated in accordance with an ASTM standard. The highest specific strength for single and double stitching was found in samples V and T60/60 of 9.53 MPa/g and 12.75 MPa/g respectively, with an improvement of 14.41% and 53.06% compared to unstitched samples. It was also found that the double stitch patterns show good agreement in improving the tensile and impact performance, either for reinforced thermoset or thermoplastic composite. The results also show that the composite samples reinforced thermoset matrix have better specific strength performance, approximately 3.58 MPa/g to 10.49 MPa/g compared to the composite reinforced thermoplastic matrix. This is due to the thermosetting matrix is generally tougher and stronger than thermoplastics. However, in impact performance, thermoplastic reinforced composite samples show higher impact strength, approximately 3.73 J/cm^2 to 4.25 J/cm^2 compared to thermoset composites due to excellent impact resistance and damage tolerance by reducing crack propagation and better stress distribution throughout the structure. The evidence from this study suggested that the stitching patterns and stitching angle gave significant effect to the performance of woven stitch kenaf composite compared to the unstitched ones. Implications of the results and future research direction were also presented.

PEMBANGUNAN KOMPOSIT POLIPROPILENA DAN EPOKSI DIPERKUAT FABRIK TENUN KENAF DENGAN JENIS JAHITAN BERBEZA

ABSTRAK

Serat semula jadi, telah mendapat perhatian daripada penyelidik dan ahli akademik untuk digunakan dalam komposit polimer kerana sifat yang mesra alam dan kelestariannya. Dalam kajian ini, teknik jahitan pada tenunan kenaf yang diperkuat oleh polimer (termoset dan termoplastik) telah dianalisis. Proses bengkalai tangan dan diikuti oleh bungkusan vakum digunakan untuk komposit termoset, manakala teknik tekanan panas digunakan untuk komposit termoplastik. Bahan yang digunakan adalah resin epoksi dan polipropilena yang bertindak sebagai pengikat dan serat tenunan kenaf sebagai tetulang. Komposit dalam corak jahitan yang berbeza dibahagikan kepada dua kategori, iaitu corak asas yang dijahit tunggal termasuk Menegak (V), Melintang (H), Condong 30° (T30) dan Condong 60° (T60). Kedua ialah corak kompleks yang dijahit dengan arah berganda, termasuk Kotak, Condong 45°/90° (T45/90), Condong 30°/30° (T30/30) dan Condong 60°/60° (T60/60). Ujian tegangan, ujian impak dan ujian hemisfera telah dinilai mengikut piawaian ASTM. Kekuatan spesifik tertinggi untuk jahitan tunggal dan berganda ialah sampel V dan T60 / 60 masing-masing 9.53 MPa/g dan 12.75 MPa/g, dengan peningkatan 14.41% dan 53.06% berbanding dengan sampel yang tidak dijahit. Juga didapati bahawa corak jahitan berganda menunjukkan kesepakatan yang baik dalam meningkatkan prestasi tegangan dan hentaman, baik untuk termoset ataupun termoplastik komposit. Hasilnya juga menunjukkan bahawa sampel komposit yang diperkuatkan oleh termoset mempunyai prestasi kekuatan spesifik yang lebih baik, kira-kira 3.58 MPa/g hingga 10.49 MPa/g berbanding dengan pengikat termoplastik komposit. Ini disebabkan pengikat termoset pada umumnya lebih keras dan kuat berbanding dengan pengikat termoplastik. Walau bagaimanapun, dalam prestasi hentaman, sampel komposit diperkuatkan oleh termoplastik menunjukkan kekuatan hentaman yang lebih tinggi, kira-kira 3.73 J/cm^2 hingga 4.25 J/cm^2 berbanding komposit termoset kerana rintangan hentakan yang sangat baik dan toleransi kerosakan dengan mengurangkan penyebaran retakan dan pengedaran tegasan yang lebih baik di seluruh struktur. Bukti dari kajian ini menunjukkan bahawa corak jahitan dan sudut jahitan memberikan kesan yang signifikan terhadap prestasi komposit anyaman kenaf yang dijahit berbanding dengan yang tidak dijahit. Implikasi dari hasil dan arah kajian masa depan juga dikemukakan.

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ASTM	-	American society for testing and materials
HDPE	-	High density polyethylene
LKTN	-	Lembaga kenaf and tembakau negara, Malaysia
MARDI	-	Malaysian agricultural research and development institute
MN	-	Montmorillonite nanoclay
MPOB	-	Malaysian palm oil board
MRB	-	Malaysian Rubber Board
NF	-	Natural fibre
NFH	-	Natural fibre helmet
NFRCs	-	Natural fibre reinforced composites
PBS	-	Polybutylene succinate resin
PEEK	-	Poly (ether ether ketone)
PHV/PBAT	-	Poly(hydroxybutyrate-co-valerate)/poly(butylene adipate -co-terephthalate)
PLA	-	Poly (lactic acid)
PP	-	Polypropylene
PU	-	Polyurethane
PVC/EVA	-	Poly (vinyl chloride)/ethylene vinyl acetate
RTM	-	Resin transfer moulding
SEM	-	Scanning electron microscope

SWKF	-	Stitching woven kenaf fabric
TCP	-	Tributyl citrate plasticized
UF	-	Urea formaldehyde
UP	-	Unsaturated polyester

LIST OF SYMBOLS

σ	-	Stress
mm	-	Millimetre
m	-	Meter
g	-	gram
g/cm^3	-	Gram per centimetre cube
wt. %	-	Weight percentage
%	-	Percentage
MPa	-	Mega pascal
Kg	-	Kilogram
G_c	-	Fracture toughness
cm^2	-	Centimetre square
cm	-	Centimetre
s	-	Second
h	-	Hour
rpm	-	Revolution
V	-	Voltage
Hz	-	Hertz
W	-	Watt
mPa.s	-	Millipascal-second
A	-	Ampere